

chunks using a read voltage that is changed such that the reliability information is obtained.

**[0016]** The RAID controller device may be configured such that, when the calculated number exceeds the reference value, the RAID controller device sets a data value of an ECC data unit having lowest reliability among the one or more ECC data units having an uncorrectable ECC error in the corresponding order to the re-read data values, based on the reliability information, and the recovery operator may be configured to recover the one or more ECC data units having an uncorrectable ECC error in the corresponding order, based on the successfully read ECC data units, the parity having the corresponding order, and the ECC data unit having the set data value.

**[0017]** A data size of each of the plurality of data chunks may be larger than a data size of each of the plurality of ECC data units.

**[0018]** A data size of each of the plurality of data chunks may correspond to a data size of a read unit of a read operation that is performed in the one or more storage devices.

**[0019]** According to at least some example embodiments of the inventive concepts, a storage device includes a plurality of nonvolatile memory devices configured to dispersively store a plurality of data chunks, each of the plurality of data chunks including a plurality of ECC data units and a device controller configured to manage data handling operations of the plurality of nonvolatile memory devices, wherein the device controller includes, an error correction code (ECC) circuit configured to, perform an ECC decoding operation, by an ECC unit, on each data chunk from the plurality of data chunks that is read from the plurality of nonvolatile memory devices, and generate an ECC result based on the ECC decoding operation being performed, and a redundant array of inexpensive disks (RAID) controller configured to, manage information of ECC result indicators respectively indicating whether the plurality of ECC data units included in the plurality of data chunks has an uncorrectable ECC error, based on the ECC result, and recover an ECC data unit having an uncorrectable ECC error with reference to the ECC result indicators.

**[0020]** The RAID controller may be configured to receive ECC results of all the plurality of data chunks from the ECC circuit when a data chunk that includes an ECC data unit having an uncorrectable ECC error is read from among the plurality of data chunks.

**[0021]** The RAID controller may be configured such that, when a data chunk that includes an ECC data unit having an uncorrectable ECC error is read from among the plurality of data chunks and a number of ECC data units having an uncorrectable ECC error among ECC data units having a same order in each of the plurality of data chunks does not exceed a reference value, the RAID controller performs a recovery operation to recover an ECC data unit having an uncorrectable ECC error in a corresponding order, the RAID controller being configured to perform the recovery operation based on successfully read ECC data units having the corresponding order in each of the plurality of data chunks and the parity having a corresponding order.

**[0022]** The RAID controller may be configured to perform the recovery operation using only the ECC data unit having an uncorrectable ECC error, one or more ECC data units that have a same order as the ECC data unit having an uncor-

rectable ECC error, and a parity that has a same order as the ECC data unit having an uncorrectable ECC error.

**[0023]** The device controller may further include a buffer memory configured to store ECC result indicators that have been referred to in order to recover an ECC data unit having an uncorrectable ECC error in a first data chunk among the plurality of data chunks, and the RAID controller may be configured to refer to the stored ECC result indicators in order to recover a second data chunk that includes an ECC data unit having an uncorrectable ECC error among the plurality of data chunks.

**[0024]** According to at least some example embodiments of the inventive concepts, a redundant array of inexpensive disks (RAID) controller device configured control a data read operation of one or more storage devices of a RAID storage system includes a memory storing computer-executable instructions; and one or more processors configured to execute the computer-executable instructions such that the one or more processors are configured to, read data of a data stripe from the one or more storage devices, the data stripe including a plurality of data chunks and at least one parity chunk, each of the plurality of data chunks including a plurality of ECC data units which are included in a plurality of orders, respectively, determine ECC result indicators indicating which data units, from among a first plurality of ECC data units, include a first type of ECC error, the first plurality of ECC data units including each ECC data unit from among the pluralities of ECC data units included in the plurality of data chunks, determine, for each order of the plurality of orders, an error number such that the error number is a number of ECC data units that are included in the order and include the first type of ECC error, and perform a data recovery operation for a first ECC data unit from among the first plurality of ECC data units based on the error number determined for a first order, the first order being the order from among the plurality of orders in which the first ECC data unit is included.

**[0025]** The one or more processors may be configured to execute the computer-executable instructions such that the one or more processors are configured to, perform the data recovery operation for the first ECC data unit when the error number determined for the first order has a first relationship with a reference value, and not perform the data recovery operation for the first ECC data unit when the error number determined for the first order does not have the first relationship with the reference value.

**[0026]** The one or more processors may be configured to execute the computer-executable instructions such that the one or more processors are configured to perform the data recovery operation for the first ECC data unit based on second ECC data units when the error number determined for the first order has the first relationship with the reference value, the second ECC data units being data units of the first plurality of ECC data units that did not include the first type of ECC error, the second ECC data units being data units included in the first order.

**[0027]** The one or more processors may be configured to execute the computer-executable instructions such that the one or more processors are configured to perform the data recovery operation for the first ECC data unit by performing an XOR operation on the second ECC data units and the at least one parity chunk when the error number determined for the first order has the first relationship with the reference value.